[Title of the Invention]

Magnetic Disk Drive and Control Method of the Drive

[Field of the invention]

The present invention is related mainly to a technology to reduce power consumption in a magnetic disk drive. Especially, the present invention is related to a method of idle seek of an actuator carrying magnetic heads, and to a magnetic disk drive which employs this method.

[Background of the invention]

When data or control signals are issued to a magnetic disk drive from a host unit which controls output/input of data, the magnetic disk drive moves an actuator carrying magnetic heads toward one of plural tracks which are formed in concentric circles around a rotating axis of a magnetic disk medium (seek operation), and positions the actuator on a target track (following operation). Next the disk drive writes the data on an appointed area (sector) in the target track or reads out the data from the appointed area. Herein, each track has plural fan formed recording areas and each of these areas is called a sector usually.

On the other hand, when data or control signals have not been issued to a magnetic disk drive from a host unit, namely there is no access operation, the magnetic disk drive does not work as an external storage device and an idle seek is executed in consideration of data reliability. The idle seek is defined

as that, when no access is ordered by the host unit, an actuator is moved to a radius direction on a rotating magnetic disk medium.

When a head follows a constant track area on a magnetic disk medium successively for long time, it is occurred that the magnetic head clashes or contacts physically with the track area and the data written on the track area are lost. The purpose of the idle seek is to prevent data loss caused by the above problem, and the idle seek gives an additional effect such as to remove dust stuck to magnetic heads.

Some technologies concerning to the idle seek are disclosed. It is disclosed in Japanese patent unexamined publication 07-182807 that the idle seek is executed under servo control utilizing usual positioning information on the magnetic disk medium for the purpose to reduce influence of a mechanical displacement caused by a lapse of time. In this method, it is necessary always that, an electronic circuit (read-write circuit) is powered up to read out the servo information from the magnetic disk medium, and sense current is provided to an MR head which is a magnetic head for reading out.

In the conventional idle seek, as described above, which is executed under servo control utilizing the positioning information on the magnetic disk medium, it is necessary that an electronic circuit for reading the information is powered up at all times to use the positioning information recorded on the

magnetic disk medium. It is difficult to reduce power consumption of the electronic circuit. Further, to drive the MR head having a magneto-resistive effect element, a sense current has to be supplied to the magneto-resistive effect element; therefore, this matter not only prevents the MR head from a long life but increases power consumption also.

The increase of the power consumption causes increase of a battery capacity in a portable system such as a notebook personal computer, etc. in which carries a magnetic disk drive, and a power saving of the magnetic disk drive is required by the portable host system.

An idle seek technology in which the positioning information on the magnetic disk medium is not utilized, is disclosed in Japanese patent unexamined publication 07-262539. In this disclosure, an idle seek technology is disclosed, in which an actuator is moved under velocity control utilizing voltage generated by back electro-motive force (hereinafter referred to as back electromotive force) in a voice coil motor (VCM) without using the servo information from the magnetic disk medium, namely without providing the sense current to an MR head and without reading out the positioning information on the magnetic disk medium.

However, in this conventional technology, the actuator is moved so that the back electro-motive force is balanced with a voltage supplied to the VCM, namely, this operation is based on

an open loop control by a kind of an analog circuit of hardware. Actually, we, the inventors of the present invention, found that, because the back electro-motive force was affected and varied by a variation of VCM temperature, accurate control of the idle seek could not be achieved and the idle seek by this conventional technology did not have sufficient reliability.

At start moment of an idle seek, a temperature of a coil in the VCM is relatively high, and, as the coil is cooled gradually, the back electro-motive force is affected and varied, then accurate velocity control can not be attained. Accordingly, the back electromotive force has to be calibrated adequately by the control information read out from the magnetic disk medium.

[Summary of the invention]

In a magnetic disk drive having

a processing unit which controls the magnetic disk drive,

an MR head which reads information on a magnetic disk medium,

a read-write IC which has a function to amplify the information read from the magnetic disk medium and a function to turn on/off sense current to the MR head, and

an electronic circuit which has a function to detect back electromotive force from a VCM actuator, a function to convert an analog value of the back electro-motive force detected to a digital value, and a read-write channel to transfer the amplified readout information signal to the processing unit,

velocity control utilizing the back electro-motive force from the VCM actuator, is calibrated soon after a start of the idle seek which is executed under conditions in which the sense current is shut off and the read-write IC and the read-write channel are powered out.

Namely, the calibration is executed as follows: the sense current is turned on, the read-write IC and the read-write channel are powered up, and the information on the magnetic disk medium is read out. This calibration is executed regularly or irregularly. Further, the processing unit has a function by which an accurate positioning of the magnetic head on the magnetic disk medium can be attained.

[Brief description of the drawings]

Fig.1 is a block diagram of a magnetic disk drive and only part being necessary for explaining the present invention is described in this drawing.

Fig.2 is a drawing showing the concept of the idle seek in the present invention.

Fig.3 is a flow chart showing the procedure of calibration of various parameters for the velocity control, in which the sense current is provided to the MR head, an RW system LSI is powered up, and a track number is taken in.

Fig.4 is a flow chart showing a detailed procedure for the calibration of a velocity and a timer value in the present invention.

Fig.5 is a plane diagram explaining a magnetic disk drive to which the present invention is applied.

Fig.6 is a side view diagram explaining a magnetic disk drive to which the present invention is applied.

[Description of the preferred embodiments]

First, a magnetic disk drive to which the present invention is applied, is explained referring to Fig.5 and Fig.6. The magnetic disk drive comprises a sealed enclosure 50 (Fig.5), disks 14 which are magnetic recording media, a spindle motor 52 which supports and rotates the disks 14, head assemblies 54 which has respectively suspension arms and magnetic heads to read out information from the disk 14, a swing arm including a pivot shaft 56 which supports the head assemblies 54 and swings the head assemblies on the disks, a voice coil motor 16 which drives the swing arm, a control circuit board 17 which makes the magnetic head write to the disk 14 and read from the disk 14, a controller (not shown in the Figs.) which controls movements of the spindle motor 52 and the voice coil motor 16, and a printed wiring board 58 which connects these elements electrically.

The disks 14, the spindle motor 52, the head assemblies 54, a part of the printed wiring board 58, and the voice coil motor 16 are inside of the enclosure 50 and are sealed by the enclosure 50. The spindle motor 52 is a in-hub type motor in which a hub to fix the disks is placed at the outermost and a rotor and a stator are built in the hub, and is built on a base

plate of the enclosure 50. The disk 14 is an important component which determines data storage capacity of the magnetic disk drive. Usually, the drive provides one disk or several disks corresponding to a storage capacity. In the magnetic disk drive applying the present invention, the disks 14 and disk spacers 60a (Fig.6) are inserted alternately on the hub. The disk clamp 60b fixes the disks 14 on the spindle motor 52 by clamping a pile of the disks to axial direction of the spindle motor 52.

The disk drive has several swing arms corresponding to number of disks 14. Each swing arm comprises sliders 15 which carry the magnetic head, and the suspension arms 62. The swing arm is fixed to the base plate through the pivot shaft 56 so as to rotate freely. A dual head which is a combination of a thin film head for writing and a magneto resistive effect type head for reading is employed as the magnetic head and is built in each slider 15. Further, as the magnetic head, an inductive head, a thin film head, a MIG head, a GMR head, and a TMR head can be employed.

In the magnetic disk drive to which the present invention is applied, a rotary actuator and a positioning method using servo information on a data surface of the disk, are employed, and each track has servo information which is readable periodically. The servo information is written on a position to which an MR head is positioned at writing by the inductive head (not shown in Fig.).

Next, an embodiment of the present invention is explained referring to the drawings.

Fig.1 is a block diagram of a magnetic disk drive and only part being necessary for explaining the present invention is described in this drawing. The magnetic disk drive comprises a head-disk assembly (HDA) and a printed circuit board assembly (PCBA).

A CPU 10 is a processing unit which controls the magnetic disk drive according to a control program. The PCBA comprises the CPU 10 and a combination of other appointed electronic circuits. A servo control is executed by using a positioning information recorded on the disk 14. Namely, the position signal to be used in the servo control is read out by providing a sense current 18 (not shown in the Fig.) to the magnetic head 15. Small read out signal from the magnetic head 15 is amplified by a read-write IC 17 (RW IC 17), is restored to servo information 20 by a read-write channel 11 (RW channel 11), and is taken in the CPU11.

On the basis of the servo information 20, the CPU 10 sends control information to a VCM driver 13. The VCM driver 13 converts this information to a VCM drive current, sends the current to a VCM actuator 16, and then drives the magnetic head 15.

By detecting a voltage generated by a back electromotive force in the VCM actuator 16 (hereinafter the voltage is

referred to as back electromotive force), the following velocity control is executed. Namely, the back electromotive force 19 which is generated due to a movement of the VCM actuator, is detected with a detecting circuit built in the VCM driver 13, and the back electro-motive force is put out outside as a voltage signal (VCM back electro-motive force). An electronic circuit which has the similar function as described above, may be placed at outside of the VCM driver 13.

The VCM back electromotive force is digitized through a analog to digital converter 12 (A/D converter) and the digitized information is taken in the CPU 10 as velocity information. Based on the velocity information, the magnetic head 15 is moved by the similar way to the servo control process. Here, the electronic circuits (LSI) in the RW channel 11 and the RW IC 17 are not used, so the power consumed in these chips is saved.

The concept of the idle seek in the present invention is shown in Fig.2. This drawing is a time chart on which the vertical axis shows a distance of the head movement when the magnetic head moves on the magnetic disk medium along radius direction (upper side is innermost side), and the horizontal axis shows time. The vertical axis is graduated in track number and a trajectory of the magnetic head moved under the velocity control (F/W) is shown together with arrows in the drawing.

Further, periods T1, T2, and T1' (values to be set in timer) in which the velocity control F/W is executed, and ON

timings at which the read-write IC 17 (RW IC) and the read-write channel 11 (hereinafter these circuits 17 and 11 are referred to as the RW system LSI) are powered up and the sense current is provided to the MR head, are shown also in the drawing. At each of these ON timings , a calibration of various parameters, resetting of a timer, and activation of the timer are executed.

First, at [OUTcyl] position, the MR sense current is provided and the RW system LSI is powered up, and a present position (track number) is taken in from the magnetic head (MR head). Here, [Cyl] is an abbreviation for cylinder and the cylinder means an imaginary cylinder including tracks on which plural magnetic heads follow at the same time.

Next, the MR sense current is shut off, the RW system LSI is powered off, a timer of T1 seconds is activated, and the magnetic head is moved to forward direction (direction from the outermost to the innermost of the magnetic disk medium) under the velocity control (F/W control) by utilizing the back electromotive force of the VCM actuator.

After T1 seconds have elapsed, the MR sense current and the RW system LSI are turned on again, and a track position at that time [XCyl] is taken in. T1 is dependent on a diameter of the magnetic disk medium, and it is usually from several seconds to 30 or 40 seconds. The period while the MR sense current is provided, is very short in comparison with T1. Accordingly, though it is described in Fig.2 that the RW system LSI is

powered up before T1 seconds have elapsed, accuracy of these timings are not essential in the present invention.

After T1 seconds have elapsed, [INN < X < MAX] is desirable. Namely, if the track position of the magnetic head after T1 seconds is between INNCyl and MAXCyl, the seek direction is reversed and the magnetic head is moved from the innermost to the outermost as a next control step.

The MR sense current is shut off and the RW system LSI is powered off in the idle seek operation, therefore, when these powers are turned on, it is necessary that the magnetic head (MR head) passes on the magnetic disk medium on which the servo information is recorded. For this reason, the above-mentioned cylinder range is provided beforehand and the condition for reversing of the seek is eased.

Next, the MR sense current is shut off and the RW system LSI is powered off, a timer of T2 seconds is activated, and the magnetic head is moved to reverse direction (RVS direction ; direction from the innermost to the outermost of the magnetic disk medium) under the velocity control by utilizing the back electromotive force of the VCM actuator. After T2 seconds have elapsed, the MR sense current and the RW system LSI are turned on and a track position at that time [YCyl] is taken in. In this time, [MIN < Y < OUT] is desirable. Namely, if the track position of the magnetic head is between MINCyl and OUTCyl after T2 seconds, the seek direction is reversed and the magnetic head

is moved from the outermost to the innermost as a next control step.

Then, the MR sense current and the RW system LSI is turned off, a timer of T1' seconds is activated, and the magnetic head is moved to the FWD direction again under the velocity control by utilizing the back electromotive force of the VCM actuator.

By repetition of the above-mentioned sequence, the idle seek process of the present invention can be executed continuously. The time chart in Fig.2 shows the basic concept of the idle seek of the present invention. Here, X and Y are the Cyl positions to which the magnetic head arrived as a result of the velocity control for the appointed periods (T1, T2, and T1') determined by timers without using the position information which has been used in conventional technologies. Accordingly, the arrived Cyl must be in a range with some breadth, therefore, it is necessary that control parameters are determined so that the track position as a result of the idle seek can not be outside of the outermost track or inside of the innermost track on the magnetic disk medium.

In an actual drive, the calibration is executed several times in the each period of T1, T2, T1' and more accurate velocity control is obtained. The time T1, T2, T1' needed for the movement to one direction is about 10 seconds. In this case, if X=7700 Cyl and Y=100 Cyl, a distance of the movement X-Y is about 7 mm. A velocity of the idle seek is about 0.7 mm/s. It is

allowed that X , Y is in the range of 500 Cyl, namely

INNCyl (7500 Cyl) < X < MAXCyl (8000 Cyl, the outermost)

MINCyl (0 Cyl, the innermost) < Y < OUTCyl (500 Cyl)

are allowed.

Further, though the above-mentioned allowable range for X, Y, is dependent on the accuracy of the velocity control by utilizing the back electromotive force of the VCM actuator, the range may be between about 150 Cyl and 300 Cyl being narrower than 500 Cyl, namely

INNCyl (7850 Cyl) < X < MAXCyl (8000 Cyl, the outermost)

MINCyl (0 Cyl, the innermost) < Y < OUTCyl (150 Cyl)

may be allowable.

Fig.3 is a flow chart showing the calibration procedure of various parameters for the velocity control, in which the sense current is provided to the MR head, the RW system LSI is powered up, and a track number is taken in.

After an appointed time which was set in the timer has passed, first, the MR sense current and the RW system LSI are turned on. Next, a track number of a present position is read. Here, a distance of the movement in the period set in the timer is obtained from a difference between the present track number and the previous track number, and a velocity can be calculated by using these information. The calibration of parameters for the velocity control is executed based on this velocity.

At this time, a timer value for a next idle seek is also

calculated and set to the timer. When the calculation of the timer value has been finished, the MR sense current and the RW system LSI is turned off again, the seek direction is reversed, and the velocity control is begun again.

Fig.4 is a flow chart showing a detailed procedure for the calibration of a velocity and a timer value. In the case shown in Fig.4, a previous track number =X, a present track number = Y, a timer value = T2, a timer value to be set next = T1', a target velocity = V, a detected velocity = V', a present velocity detecting gain obtained from the back electromotive force of the VCM actuator = K, a next velocity detecting gain to be obtained next from the back electro-motive force of the VCM actuator = K', and a target track number = OUT.

First, the velocity V' of the present movement is calculated by using X, Y, and T2. By this velocity information, the velocity detecting gain K' is determined so that the next velocity becomes equal to the target velocity V. Lastly, the timer value to execute the next velocity control is determined with the information of the present track number and the target track number.

Through the sequence of processes shown in Fig.4, the calibration is achieved. It is essential in the present invention that, when the velocity control is executed by monitoring and utilizing the back electromotive force of the VCM in the idle seek operation which is executed after the MR sense

current is shut off and the RW system LSI is powered off, the calibration of the velocity control is executed. Accordingly, this calibration does not necessarily execute at each reversing of the seek direction. The calibration may be executed intensively soon after a start of the idle seek under the velocity control of the present invention, when temperature variation is so rapid. It is not essential in the present invention when the calibration of the idle seek under the velocity control is executed. However, it is necessary that the above-mentioned calibration and the seek control are executed before the magnetic head arrives outside of the outermost or inside of the innermost on the magnetic disk medium.

Further, in a conventional idle seek in which the positioning information is used constantly, current consumption is about 300 mA, for example, but current consumption in the idle seek of the present invention is about 200 mA and saving effect of 100 mA is obtained. This saved value is nearly equal to the sum of the MR head sense current and current consumption by the RW system LSI.

By the present invention, the velocity control is executed by using the back electromotive force of the VCM actuator, only the calibration of the velocity control is merely executed some times adequately, and resources (power for circuits and life time of an MR head) of a magnetic disk drive is utilized efficiently, therefore the positioning information recorded on

the magnetic disk medium is not used constantly, and power saving can be achieved. Furthermore, although the providing of the sense current to the MR head is stopped in substance, an accurate and reliable idle seek can be obtained.